ElectroSpark Deposited Coatings for Replacement of Chrome Electroplating

(SERDP Project 1147)

HCAT Meeting – 2 April 2003

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Report Documentation Page

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ELECTROSPARK DEPOSITION (ESD)

Process Summary

A **micro-welding** process that uses short-duration, high-current electrical pulses to deposit an electrode material on a metallic substrate. Coating is fused (true **metallurgical bond**) to substrate with such a low total heat input that the bulk substrate material remains at or near ambient temperature.

Rapid solidification produces nano-structures with unique tribological and corrosion performances.

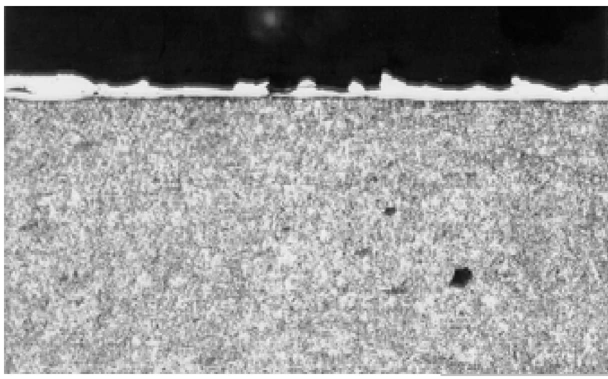
Coatings of nearly any electrically conductive metal, alloy, or cermet can be applied to metal or cermet substrates.

ACCOMPLISHMENTS

1. Selection of candidate coating materials completed.
2. Selection of substrate materials representative of Tri-Service needs completed.
3. Determined effect of wave form on coating quality.
4. High speed videography trials completed, characterization technique eliminated.
5. Completed Taguchi matrices, established electrode contact force as parameter most important for NLOS control.
6. Real-time analysis of pulse wave form used to provide feed-back to electronic force controls (patents in progress).
7. Force indicator for manual deposits completed.
8. Characterization of coatings nearing completion (wear and fatigue- preliminary results now available).

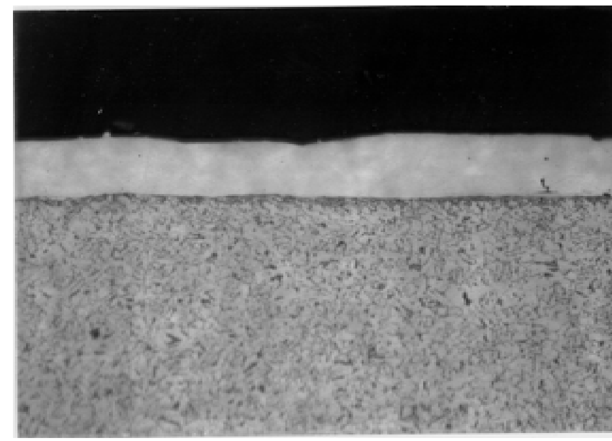
Stellite 6 on 4340 Steel

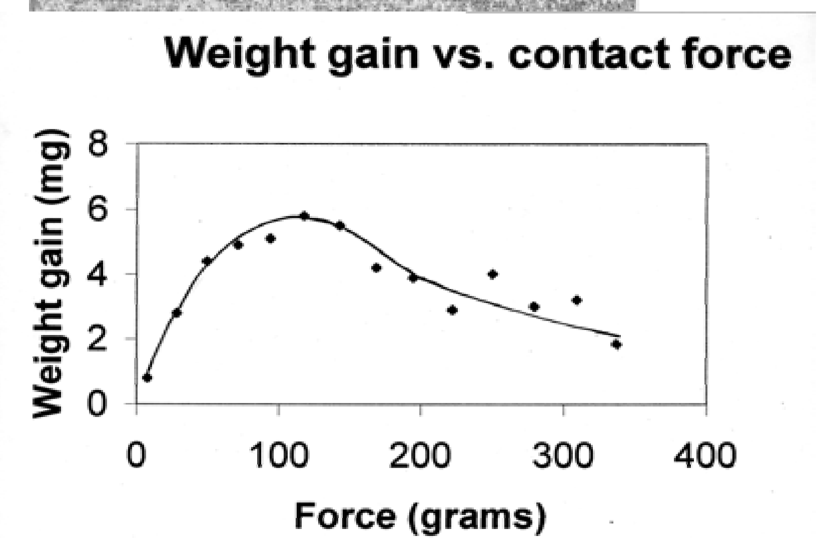
30 μF



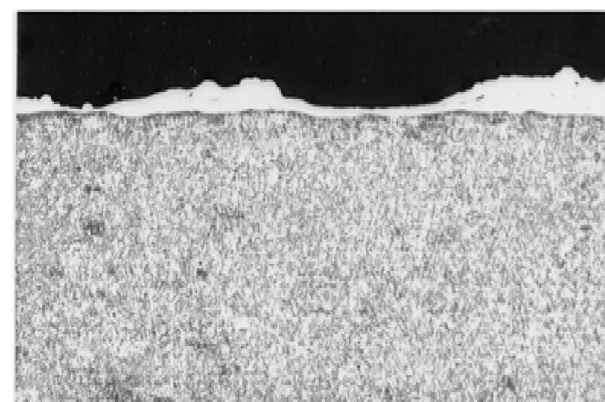
15 g force

100 g force





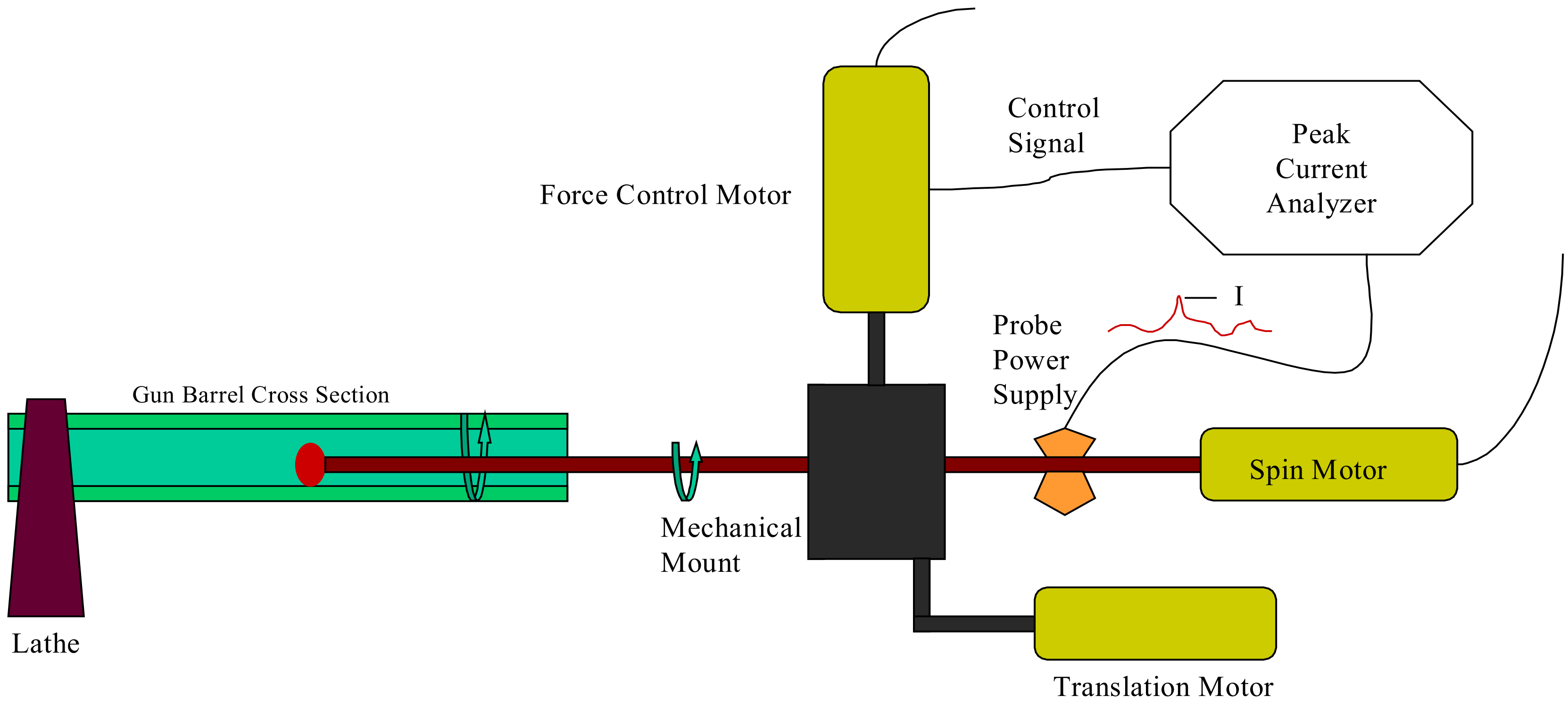
350 g force



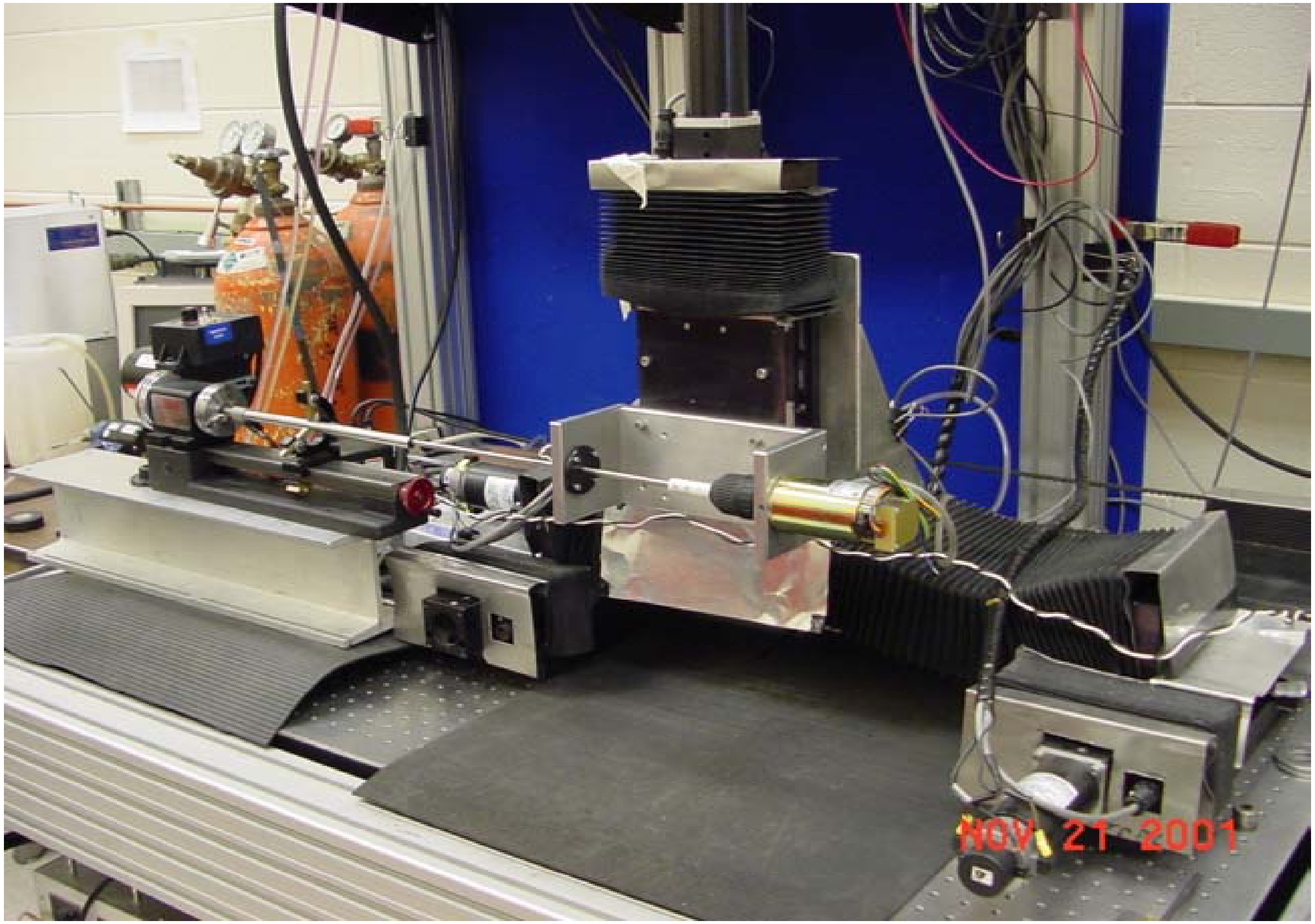
Contact Force Control
Principal Parameter for NLOS Success

- **Phase 1 – Control force in one axis (automated)**
  - –Hall-effect magnetic switches
    - *–Completed*
- **Phase 2 – Control force in multiple axes (automated)**
  - –Requires computer analysis of wave form, correlation with force, and feed back to force control module
    - *–Completed*
- **Phase 3 – Control force in multiple axes (manual)**
  - –Computer provides feedback to operator when in optimum range
    - *–Completed*

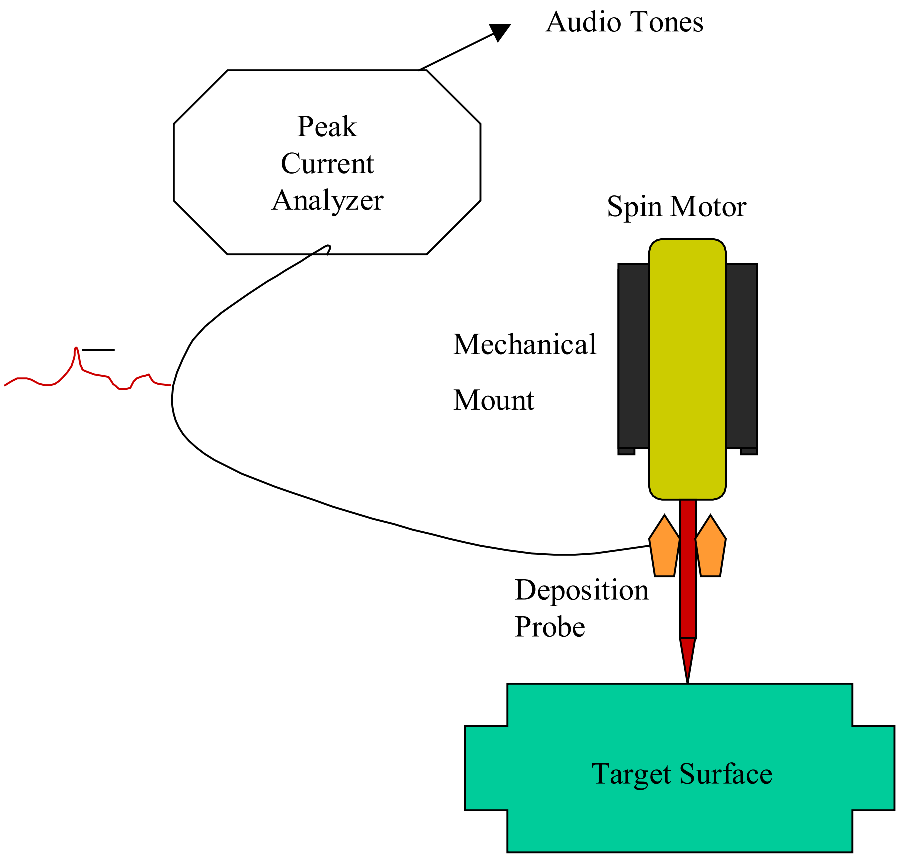
Inside Diameter (Gun Barrel)



Automated ESD Coating of 0.5" Inside Diameter Steel Tube



Hand Held Deposition



Status

- **Real-time analysis** of coating deposition parameters is being done by wave form feed-back in non-line-of-sight applications.
- **Electronic controls** have been developed to maintain optimum electrode contact force under varying NLOS conditions (patent application in progress).
- **Force control indicator** for manual applications completed.

Transition Plan

- ESTCP established for technology transition
  - Select candidate components
  - Conduct additional coupon testing specific to component or Tri-Service requirements
  - Coat components for demonstration/validation activities
  - Perform component testing: Rig or lead-the-fleet testing
  - Justify ESD use for DOD applications - perform ECAM
  - Prepare process specifications

Preliminary Wear Results

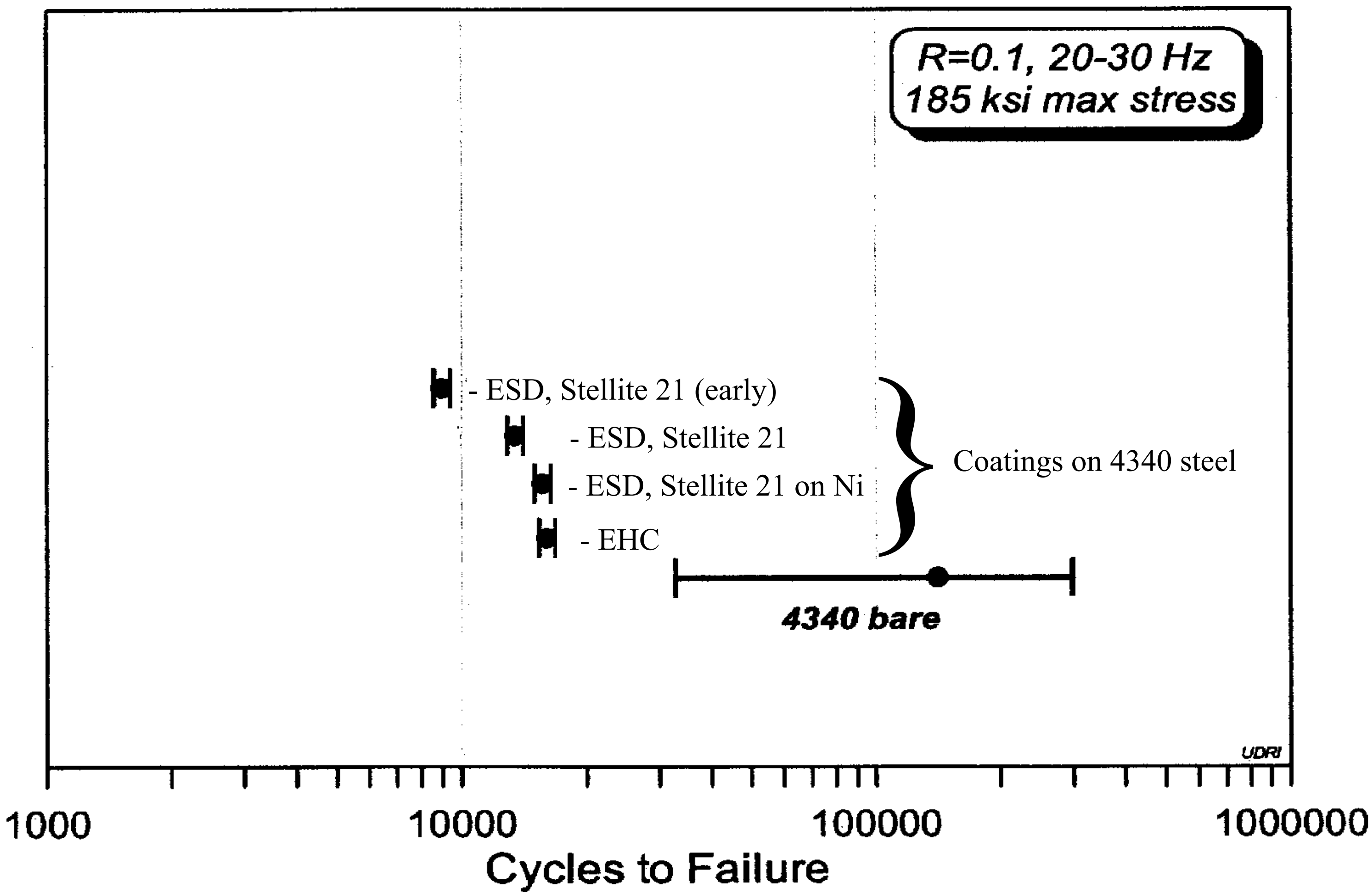
- **Materials** – Stellite 21, Stellite 12, Cr Carbide, TiAl-TiB_2, EHC
- **Test** – Pin-on-Plate, 100 to 500 grams, 440 C pin
- **Wear of Coatings-** Negligible on all except TiAl-TiB_2 (significant wear above 300 grams)
- **Wear of Pin-** 1-4 x 10^{-11} grams (highest pin wear against Stellite 12)

Preliminary Fatigue Tests

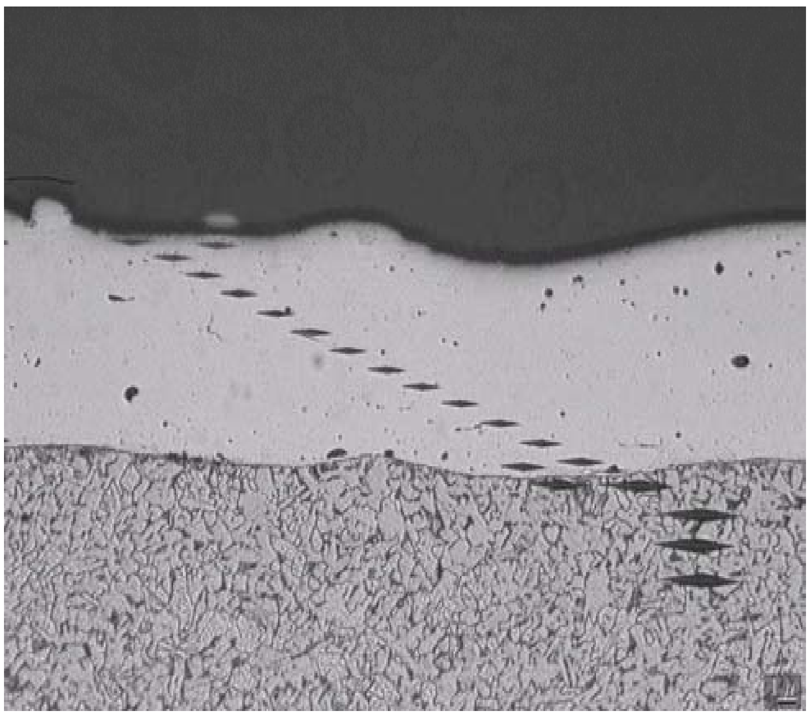
- **Materials** – Stellite 21 on heat treated 4340 steel
- **Test** – 185 ksi, R = 0.1, 20 Hz
- **Early results (**non-optimum deposition parameters**)**
  – Avg. 8965 cycles to failure
- **Later Results –** Stellite 21 only – 13,047 cycles avg.
  - St. 21 over Ni – 15,626 cycles avg.

  (for comparison, EHC coating **-** ~ 18,000 cycles)
- **Additional tests** to be completed

Preliminary Results of Fatigue Testing on ESD Coated 4340 Steel



Nano-structures Enhance Hardness of ESD Coatings



Hall-Petch effect demonstrated in hardsurface materials

Knoop hardness measured on bulk material and on ESD coating:

Knoop Hardness

Material	Bulk	ESD Deposit
Stellite 6	400	**700 – 750**
Stellite 21	300	**575 – 600**

Repair of Cr Plate by ESD